REMARKS

1. Amendments to the independent claims 1, 20, 31, and 35 were made to better clarify the novel features of the invention over the prior art. In particular, amended Claim 1 now recites a step of providing for multi-stage combining. Amended Claims 20 and 31 each recite a step of providing for multi-stage demultiplexing. Amended Claim 35 now recites a multistage spatial demultiplexer. Multi-stage demultiplexing is mentioned on page 3, lines 27-29 of the specification. A multi-stage combiner is shown in FIG. 3 and described on page 7, lines 10-19. FIG. 8 illustrates a multi-stage demultiplexer that is described on page 14, lines 1-7 of the specification.

2. Amendments to the dependent claims 21, 22, 38, and 39 were made in accordance with the amendments to the independent claims and to better clarify the novel features of the invention.

3. An amendment to claim 23 was made to correct a typographical error.

4. Applicant submits that the above-recited step of providing for multi-stage combining in the amended independent claim 1 (and hence, in the dependent claims 2-19), providing for multi-stage demultiplexing in independent claims 20 and 31 (and hence, in the dependent claims 21-30 and 32-33) clearly presents novel methods that the prior-art references neither describe nor anticipate.

   Applicant submits that the above-recited multistage spatial demultiplexer in the amended independent claim 35 (and hence, in the dependent claims 36-39) clearly presents novel structure that the prior-art references neither describe nor anticipate. Thus, the amended independent claims 1, 20, 31, and 35, (and hence, the dependent claims 2-19, 21-30, 32-33, and 36-39) should be considered patentable under 35 U.S.C. 102.

5. The above-recited novel structure and methods provide substantial improvements in system capacity and signal quality to both single antenna and antenna array systems used for communications, and therefore should be considered non-obvious, making the claims patentable under 35 U.S.C. 103.

6. Specifically, the claimed invention purposefully uses interfering signals to simultaneously enhance bandwidth efficiency and frequency diversity. By employing a **multi-stage** demultiplexer for frequency-domain combining, Applicant's invention enables superior separation of interfering signals. This enables multiple desired signals to share the same frequency channel, thus allowing substantial frequency reuse and diversity benefits.

The benefits of using a multi-stage demultiplexer (i.e., canceler, or combiner) over conventional single-stage banks of combiners is well known in the art of time domain spread spectrum, such as code division multiple access (CDMA). For example, FIG. 1 of U.S. Pat. No. 6,192,067 shows a prior-art multi-stage interference canceller. Col. 1, Lines 23-25, states "The ***multistage*** interference canceller, which generates and removes interference replicas from received signals in multiple stages, is generally expected to improve Signal to Interference Ratio (SIR)." Similarly, L.C. Andrew et. al., "Successive Interference Cancellation for Multiuser Asynchronous DS/CDMA Detectors in Multipath fading Links", IEEE Trans. Comm., Vol. 46, No. 3, Mar. 1998, presents plots of receiver performance that show that a multi-stage canceller (i.e., a multi-stage demultiplexer) significantly increases the performance of CDMA receivers relative to single-stage cancellers, particularly when compared to a maximum-likelihood detector, ***which is similar to the type of single-stage detector shown in the cited and relied upon reference, Agee***.

No other prior-art reference uses a **multi-stage** demultiplexer for frequency-domain cancellation of signals having uncoded (i.e., characterized by an absence of orthogonal coding) frequency dependent spatial gain distributions.

7. **None of the prior-art references teach to use multi-stage demultiplexing to separate signals having unique frequency dependent spatial gains:**

Agee illustrates a **single-stage** decoder (FIG. 7B) for decoding a data sequence encoded on multiple sub-carrier frequencies. That is, the despreading code generator 191 shown in FIG. 7B provides **only one** despreading code weight to each in-phase and quadrature-phase signal of each sub-carrier frequency. Thus, only a **single stage** of code weights are applied to the input signal, and the code weights are adapted to "maximize the signal-to-interference-and-noise ratio of the despread message sequence in the preferred embodiment…" In FIG. 12, co-channel interference is removed by a bank of combiners 332 shown coupled to a **plurality of antennas**. The combiners 332 are adapted to perform "multi-antenna reception" and "spatial filtering" (Col. 15, line 4), which requires **more than one antenna**. Even if antenna array 326 was a single antenna element, the combiners 332 are still only **single stage**.

Raleigh et. al. illustrates a well-known diversity combiner that channelizes the received signal from two or more antennas and performs a common form of diversity combining for each set of channelized signals. No frequency-domain demultiplexing or multi-stage cancellation is shown.

The Novel Physical Feature of the Claims Provide New and Unexpected Results and Hence Should Be Considered Non-obvious, Making the Claims Patentable Under 35 U.S.C. 103.

8. Applicant submits that the above-recited novel features in the independent claims, and hence in all claims, provide new and unexpected results and therefore should be considered non-obvious, making the claims patentable under 35 U.S.C. 103.

9. Specifically, by providing multi-stage demultiplexing instead of single-stage demultiplexing (such as maximizing a signal-to-interference ratio described by Agee and Raleigh), a substantially higher degree of interference cancellation is

achieved. The cancellation afforded by this method is far superior to the performance of any prior-art frequency-domain combining device or method. Furthermore, the method and apparatus claimed in the present invention enables a communication system comprised of one or more receivers to be substantially free of electromagnetic interference regardless of the electrical characteristics or physical orientation of the electromagnetic receivers. The claimed invention enables superior cancellation without requiring a predetermined spatial separation between transmitters and regardless of the number of angles of arrival of interfering signals.

10. Applicant's invention purposefully generates interfering signals and thus, enables determination of the ratios of interference. Alternatively, single-stage optimization is typically performed when no other technique can adequately determine unknown quantities in a measurement. For example, optimization is performed to suppress unknown (and uncontrollable) signals that interfere with **one** desired signal. Unfortunately, the application of optimization (such as adaptive signal processing) to a system having **multiple** interfering desired signals does not exploit the ability to measure interference ratios or control those ratios. However, Applicant's invention deliberately transmits interfering signals having measured (i.e., known) relationships in order to facilitate separation of the signals, and then uses a multi-stage demultiplexer to greatly improve the performance of the demultiplexing process. This allows Applicant's invention to increase the capacity of a frequency-limited communication channel. Applicant's invention exploits the ability to control the interfering signals to determine ratios between the interfering signals from which weights can be derived. These weights are substantially more effective for canceling interference than weights generated by a **blind** processing technique, such as preferred in Agee.

11. **None of the Prior-Art Interference Cancellers Can Provide these New and Unexpected Results.**

Agee's spread-spectrum system employs only single stage code nulling. This prevents the Agee system from achieving the performance of a multi-stage demultiplexer, which leads to new and unexpected results of Applicant's invention, including superior system capacity, bandwidth efficiency, and interference rejection.

The Andrews system (cited herein) employs a multi-stage demultiplexer in systems employing both time-domain processing and orthogonal coding. Consequently, the Andrews reference fails to achieve the improved performance benefits of frequency-domain combining. It is well known that frequency-domain combining achieves superior performance compared to time-domain combining. For example, Applicant's paper, "*Exploiting Frequency Diversity in TDMA Through Carrier Interferometry*", Proceedings of *Wireless 2000, 12th International Conference on Wireless Communications*, Vol. 2, pp. 10-12, Calgary, Canada, July 10-12, 2000, illustrates 5dB to 8dB performance gains for frequency-domain combining with only a modest amount of frequency diversity.

Because the novel physical features of Applicant's device provides new and unexpected results over any prior-art reference, and the addition of Applicant's device to the prior-art devices of the cited and applied references results in a substantial improvement in the performance of these prior-art devices, Applicant submits that these new results indicate non-obviousness of the novel physical features and hence, patentability. Accordingly, Applicant respectfully requests reconsideration and allowance of the present application with the above new claims.

Additional Reasons Militate in Favor of Non-obviousness

12. In addition to the above new and unexpected results, Applicant submits that additional reasons militate in favor of patentability, as follows:

13. **Unrecognized Problem:** Up to now, insofar as Applicant is aware, the art contained no indication of the desirability of applying multi-stage demultiplexing to frequency-

domain combining. In particular, the prior art teaches that the best way to perform frequency-domain combining is to use a single-stage optimization process. On the other hand, multi-stage processing is typically applied in the time domain to CDMA signals having well-defined orthogonal codes. The prior art fails to teach the application of multi-stage demultiplexing to typically non-orthogonal, interfering signals spread in the frequency domain. Consequently, the prior art overlooks the substantial performance advantages enabled by the present invention. The discovery of this problem, as well as the concomitant ability to apply a multi-stage demultiplexer in a novel way, results in a significant advancement in multi-carrier processing. Superior interference cancellation and improved system capacity are submitted to be important advances, clearly indicating the non-obvious nature of the invention.

The Cited but Non-Applied References

14. The prior-art references made of record and not relied upon have been studied, but are submitted to be less relevant than the relied-upon references. In particular,

    a. Tsujimoto (U.S. Pat. No. 6,075,808) relates to time diversity radio systems and shows a Rake-based time-domain equalizer and matched filter. Tsujimoto does not describe frequency-domain processing.

    b. Fujimoto et. al. relates to frequency-domain processing, and in particular, to correcting for channel-induced distortions in a multicarrier signal. Signal weighting and combining is performed relative to signals received by different antennas. However, the signals are combined to compensate for frequency-dependent spatial gains rather than exploit the spatial gains to carry more data. Furthermore, no multi-stage cancellers are shown or described.

c. Abu-Dayya relates to space-diversity systems employing time division multiple access. No frequency-domain demultiplexing or multi-stage cancellation is shown.

Very respectfully,

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Version with markings to show changes made to the Claims

1. A method for spatial demultiplexing interfering signals comprising the steps of
   - transforming a discreet-time input signal into a plurality of spectral components,
   - computing a set of weights for each of a plurality of channels with respect to channel fading,
   - applying said weights to said spectral components, and
   - <u>providing for multi-stage</u> combining <u>of</u> the weighted spectral components to cancel co-channel interference.

20. A method for spatial demultiplexing interfering signals comprising the steps of
   - transforming a discreet-time input signal that includes a plurality of interfering signals into a plurality of spectral components, the spectral components having differences in either or both amplitude variations and phase variations, and
   - <u>providing for multi-stage demultiplexing of</u> [separating] the interfering signals by processing either or both the amplitude variations and the phase variations of the plurality of spectral components <u>in a multi-stage demultiplexer</u>.

21. The method of claim 20 wherein the step of transforming the discreet input signals includes a step of separating a plurality of interfering information signals modulated on each of the spectral components and passing the information signals to the step of [separating] <u>providing for multi-stage demultiplexing of</u> the interfering signals.

22. The method of claim 20 wherein the step of [separating] <u>providing for multi-stage demultiplexing of</u> the interfering signals involves a constellation processing method.

23. The method of claim 20 wherein the discreet-time input signals are derived from a plurality of received signals, the received signals being transmit signals that have <u>propagated</u> [propogated] in a free-space or guided-wave environment after being transmitted by a plurality of transmitters.

31. A method for spatial demultiplexing interfering signals comprising the steps of

- transforming a receive signal that includes a plurality of interfering signals into a plurality of diversity components, the diversity components having differences in either or both amplitude variations and phase variations, and
- providing for multi-stage demultiplexing of [separating] the interfering signals by processing either or both the amplitude variations and the phase variations of the plurality of diversity components in a multi-stage demultiplexer.

35. An apparatus for spatially separating a plurality of interfering received signals, each of the received signals having a different amplitude-versus-frequency profile, the apparatus comprising

- a diversity receiver adapted to separate [for separating] the received signals into a plurality of frequency components, and
- a multistage spatial demultiplexer adapted to separate [for separating] the received signals in the frequency components.

38. The apparatus of claim 35 wherein the spatial demultiplexer comprises

- a weight generation unit adapted to generate [for generating] a plurality of weights based on the amplitude-versus-frequency profiles of the received signals, and
- a multistage combining unit adapted to perform multi-stage [for] weighting and combining of the plurality of received signals using the generated plurality of weights to enhance signal to interference of at least one of the received signals by canceling interfering signals.

39. The apparatus of claim 35 wherein the multistage spatial demultiplexer is adapted to separate the [separates] received signals by comparing the received signals to a constellation of points.